RECORDING TEMPERATURES OF AGRICULTURAL PRODUCTS IN TRANSPORTATION VEHICLES WITH COMPUTER-COMPATIBLE RECORDERS

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PREFACE

The information in this report constitutes a beginning step in the application of computer technology to the monitoring of transit environments of a variety of perishable agricultural products. The combination of the computer and solid-state electronics can be a powerful tool for increasing data-gathering efficiency in the transit environment. This report addresses temperature monitoring with equipment primarily for use in research and other special situations where the researcher has control over the transportation vehicle. As computer technology and techniques become increasingly applied in the transportation industry, other environmental parameters can be monitored and even controlled in transit. This would eventually lead to complete control of the refrigeration system and cargo environment in transit, thus insuring a higher quality product for the consumer.

Appreciation is expressed to P. L. Breakiron, Chief, Transportation and Packaging Research Laboratory, Agricultural Marketing Research Institute, Beltsville, Md., for his guidance in this project and to the following persons for their expert advice and cooperation: Members of Data Systems Application Division, in particular, Robert Kling and George Ratte, computer specialists; and David R. Massie, agricultural engineer, Instrumentation Laboratory, Agricultural Marketing Research Institute, Beltsville, Md. Other researchers who, through using test instruments, provided valuable information without which adequate testing could not have been completed, include B. Hunt Ashby, William A. Bailey, Anton Bongers, James Fountain, and Thomas Moffitt.

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By W. G. Kindya, W. R. Miller, and L. A. Risse 1/

ABSTRACT

Information is presented to inform readers of a practical application of solid-state electronics and the computer to the measurement, recording, and analysis of temperature data in transportation vehicles. Primary requirements of a temperature recorder for use in the transportation environment are discussed. Major components of the system evaluated include self-contained recorder, playback unit, computer terminal, interface, and computer programs. An example of computer job control statements, a program to plot data, and sample output graphs are presented in the appendix. A self-contained, magnetic-tape cassette recorder records temperature data in transit. Data are transmitted by a computer terminal via commercial telephone lines to a computer center for processing with preprogramed instructions. Output is transmitted back to the terminal and stored for future reference. The system takes advantage of the computer's speed and accuracy and is economical when used on a time-sharing basis.

KEYWORDS: Data processing, computer, temperature, transit, agricultural products, recording.

BACKGROUND

A primary consideration in transporting perishable agricultural products from growing areas to the marketplace is the maintenance of optimum transit temperature. If commodity temperatures exceed tolerable limits by only a few degrees, consequences can be serious. This is especially true if the optimum transit temperature of a commodity is at or near its freezing point or if live animals are being transported in a situation where the temperature of their environment may become too cold or too warm.

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Temperature-monitoring equipment is necessary for measuring and recording cargo temperatures in transit to enable shippers, carriers, receivers, and researchers to determine if the correct temperatures are being maintained by the temperature-control system. It is often necessary to measure pulp temperatures of packaged produce and ambient air inside packages. This information may be used in the development and design of new temperature-control equipment for use in transportation of perishables.

The data-acquisition system described in this report is primarily a tool for use by researchers and engineers who gather, process, and analyze large amounts of temperature data from transportation vehicle environments.

REQUIREMENTS OF A DATA RECORDER FOR INTRANSIT USE

Reliability

The researcher must have a reliable data-acquisition system if sound conclusions are to be based on the data obtained. Transportation tests involve considerable planning, resource input, and monetary involvement. An unreliable data-acquisition system could, therefore, result in considerable economic loss.

Self-Contained Recorder--No External Power Requirement

Vehicles transporting agricultural products vary widely in the type of power available for use. A recording instrument that depends on an external power source would be limited in its application to all transport modes (air, ship, rail, truck). In addition, a power failure or temporary shutdown of the temperature-control equipment could result in losses of data.

Low Power Usage

A recorder must often be aboard a transit vehicle for long periods of unattended operation. This requires a low-power-drain recorder that would record and store data automatically over long periods of time for future access and evaluation.

Minimal Maintenance and Simple Operation

Low maintenance and simple operation are essential for an instrument to be used effectively in field experiments and test shipments by many different people. Field operation of the instrument should be limited to such simple tasks as battery charging, connecting sensors to instrument, and checking calibration.

Durability

The intransit recorder must withstand vibration, shock, temperature extremes, relative humidity extremes, moisture, and rough handling.

Compactness

Size and weight of data-recording equipment will often be limited by the mode of transportation. Payload capacity is required in transportation vehicles for a shipment to be economically justifiable, and carriers may be reluctant to include bulky or heavy monitoring equipment which may reduce the payload. Recorders must also be compact for shipment from one location to another.

Multipoint Recording

Multipoint recording and remote temperature measurement are necessary to monitor many locations within and outside the transport vehicle with one recorder using different length temperature sensor leads. The multipoint-recording feature requires reliable channel switching, separation, and identification.

Ease of Data Retrieval

This feature is necessary for data evaluation and analysis by high-speed data-processing equipment. It eliminates the need for one to manually read, compile, and perform mathematical operations with data, as is necessary with paper-chart recording instruments. Manual manipulation of data is costly and highly subject to errors. A desirable feature of this system is that data may be cataloged and stored for future reference.

COMPONENTS OF SYSTEM TESTED (Figs. 1 and 2)

1. Temperature-data recorder meeting the requirements stated above.

2. Playback unit to read data from the recorder storage unit.

3. Computer terminal to transmit data to a computer center for processing and analysis.

4. Interface between the playback unit and the computer terminal.

5. Set of computer programs to process the data for analysis and printout.

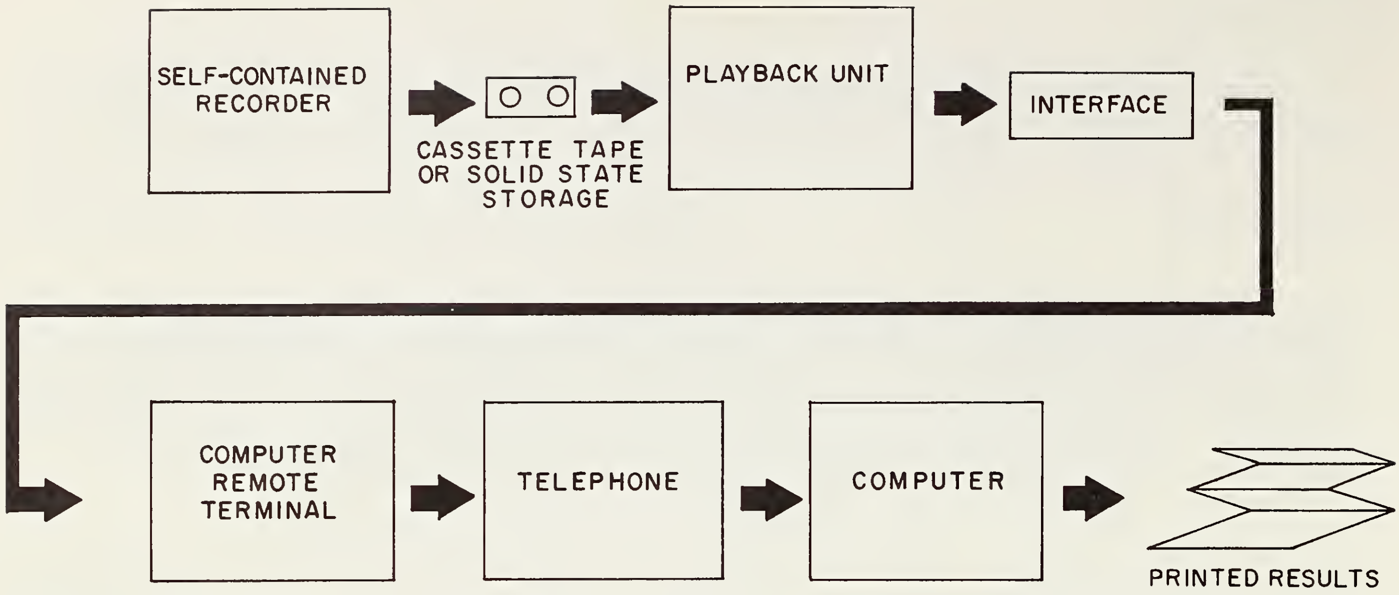


Figure 1.--Data flow diagram depicting elements of computerized data acquisition and processing system.

Figure 2.--Playback unit, interface, computer terminal, and telephone were used to transmit data from a remote field location to computer center in Washington, D.C.

In testing the pilot system, instruments were used in both stationary tests and commercial test shipments of agricultural products by railroad, truck, ship, and aircraft.

Instruments were exposed to widely varied environments during testing. They were placed aboard refrigerated trailers and containers transporting fruits and vegetables (figs. 3 and 4). Thermostat settings on these vehicles ranged from 34° to 55° F. During stationary tests, instruments were exposed to temperatures ranging from -10° to 100° F. Test instruments were also placed on ocean-going ships in livestock test shipments and on aircraft to record environmental temperatures in transit. The tests lasted up to 16 days, with recording intervals varying from 1 minute to several hours.

The instruments performed satisfactorily in both stationary and transit tests. Problems, however, occurred with individual sensors during testing. These problems were traced to thermistor temperature sensors damaged during

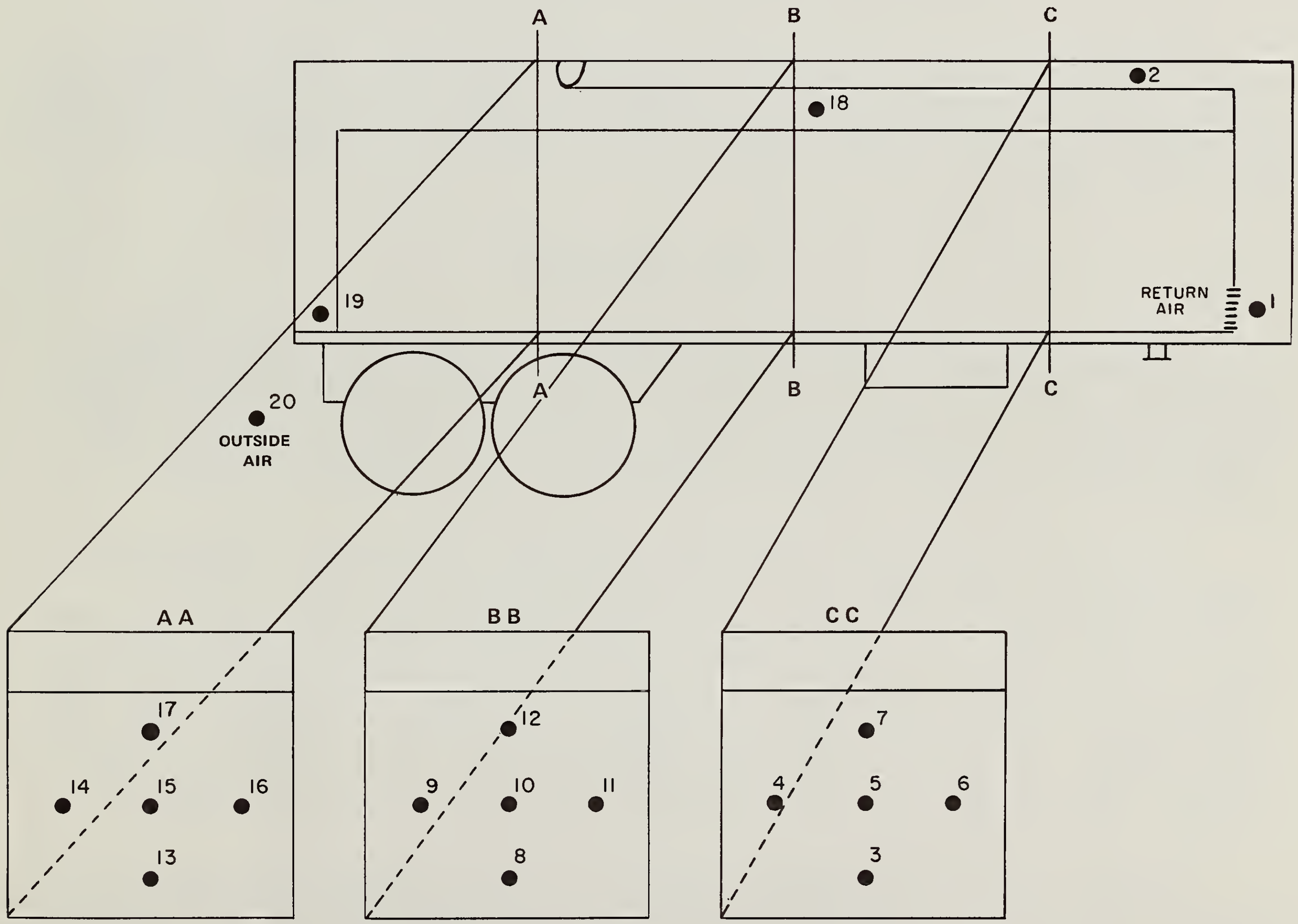


Figure 3.--Location of thermistor temperature sensors used to monitor temperatures in a transport vehicle.

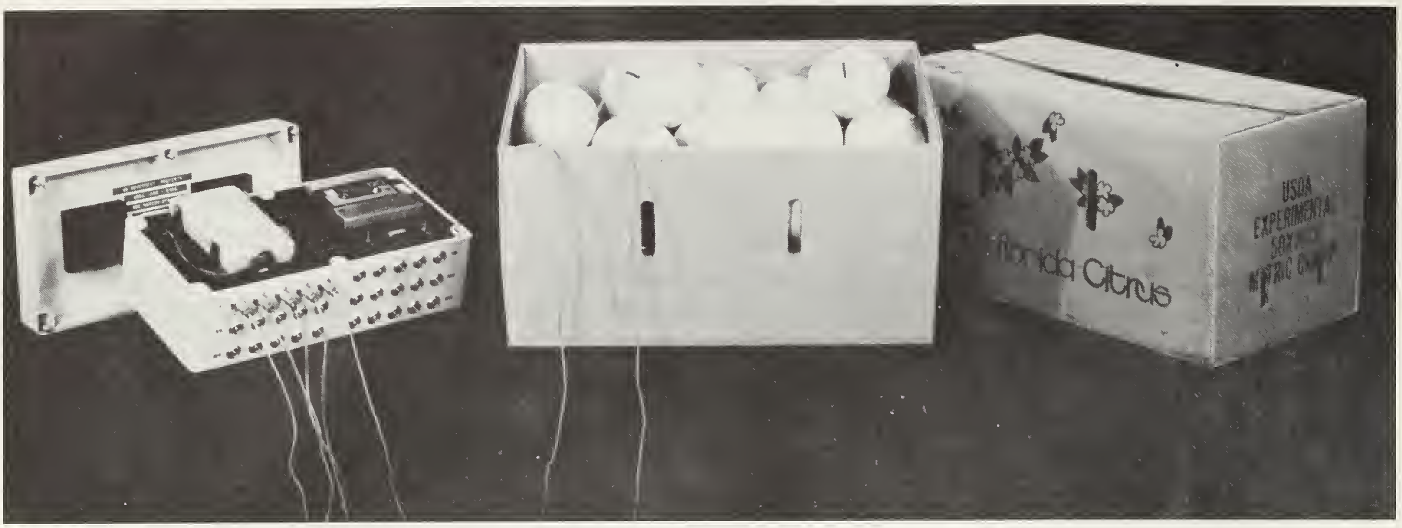


Figure 4.--Self-contained, 30-channel, cassette tape recorder with thermistor temperature sensors inserted in grapefruit.

insertion into the test product or damaged by livestock. Damage of individual sensors did not adversely affect readings from other sensors, since any number of sensors up to the maximum capacity of the particular instrument can be used at any one time.

DATA PROCESSING

Temperatures were recorded on a commercially available multichannel, self-contained, magnetic-tape data recorder.2/ Temperatures were sensed by thermistor temperature sensors fitted with polyvinyl-chloride-covered cable and weatherproof instrument connectors. Data were stored on magnetic tape cassettes during transit tests and transmitted by a computer terminal to a data-processing center for processing with preprogramed instructions.

A computer terminal is recommended because it eliminates intermediate steps necessary when paper-tape or punchcard systems are used. Use of a terminal also gives the operator the opportunity to "converse" with the computer, make changes in stored programs, and process data on a time-sharing basis. The computer terminal is portable and can be carried and used at any location with electricity and a telephone. Data from the cassette tape were sent through the terminal to a main computer center over commercial telephone lines. The processed data and analysis output was printed directly at the terminal for instant use by the operator and stored for future reference.

Examples 1-3 in the appendix show the computer control statements used to process the data, and examples 4-6 show computer-generated output of temperature data recorded by the magnetic tape recorder during a test in a refrigerated

2/ Grant Magnetic Tape Temperature Recorder, Model CRW, Grant Instruments, Ltd., Cambridge, England.

transport vehicle. These examples are included to show how we chose to control the data flow on our particular computer (IBM 370/168). This prompt program or command list would only apply to IBM systems using OS/VSZ TSO release 3.7 or higher. The programs written in COBOL and FORTRAN languages that are used to process data from a particular type of recorder will be available at a later date, when fully refined and tested.

Data processing is started by the operator's typing a short series of commands on the computer terminal. Once the data transmission is started, the playback unit, interface, and the computer terminal are automatically controlled from the computer center.

The data can be recalled at any time and evaluated by any statistical method. Data were processed using the Statistical Analysis System (SAS).[3/]

3/ Statistical Analysis System, Version 76.5. Documentation: A User's Guide to SAS 76. SAS Institute, Box 10066, Raleigh, N.C. 27605.

APPENDIX

Example 1

STATEMENTS USED BY REMOTE-TERMINAL OPERATOR TO BEGIN DATA PROCESSING

1. Execute SP

   a. Enter name of data file

2. Transit test data

   b. Enter name of SAS program

3. Transit test analysis

   c. Enter number of copies to be printed

4. 2

   d. Enter C or F for temperature conversion or C,LIST or F,LIST for listing only

5. F,LIST

   e. Enter type of instrument, single or multiple

6. Single

Statements 1 through 6 are typed into the computer terminal by the operator to start the data processing. Statements a through e are computer-generated prompts to aid the operator.

Statement 1 directs computer to the command list (example 2).

Statement 2 directs computer to a particular data set.

Statement 3 directs computer to an analysis program (example 3).

Statement 4 orders number of copies to be printed.

Statement 5 specifies output in either degrees F or C and either listed for printing only or stored for future recall.

Statement 6 designates the type of instrument used and directs computer to a particular stored program that contains information for conversion of data from cassette tape to a computer-compatible language and format.

Example 2

PROMPT PROGRAM CONTROL STATEMENTS

LINE STATEMENT

```
PROC 0 R(*) DSP(CATLG)
 TERM NOL NOS LINESIZE(133)
A1: WRITE ENTER NAME OF DATA FILE
    READ &DATANAME
    IF &LENGTH(&DATANAME) GT 28 THEN DO
      WRITE ***DATA FILE NAME TOO LONG - EXCEEDS 28 CHARACTERS***
      GOTO A1
    END
    IF &DATATYPE(&SUBSTR(1:1,&DATANAME)) = NUM THEN DO
ER1:  WRITE ***INVALID DATASET NAME - 1ST CHARACTER OF EACH NODE MUST BE
      WRITE    ALPHABETIC***
      GOTO A1
    END
    SET &POS = 1
    DO WHILE &POS LE &LENGTH(&DATANAME)-1
      IF &SUBSTR(&POS:&POS,&DATANAME) NE . THEN +
        SET &POS = &POS + 1
      ELSE DO
        IF &DATATYPE(&SUBSTR(&POS+1:&POS+1,&DATANAME)) = NUM THEN +
          GOTO ER1
        ELSE +
          SET &POS = &POS + 1
      END
    END
A2: WRITE ENTER NAME OF SAS PROGRAM
    READ &SASPGM
    IF &DATATYPE(&SUBSTR(1:1,&SASPGM)) = NUM THEN DO
      WRITE ***1ST CHARACTER MUST BE ALPHABETIC***
      GOTO A2
    END
A3: WRITE ENTER # OF COPIES TO BE PRINTED AT DSAD
    READ &COPIES
    IF &COPIES GT 99 THEN DO
      WRITE ***COPIES CANNOT EXCEED 99 ***
      GOTO A3
    END
A4: WRITE ENTER C OR F FOR TEMPERATURE CONVERSION
    WRITE       OR C,LIST OR F,LIST FOR LISTING ONLY
    READ TEMP,LIST
    IF &TEMP = C THEN GOTO A5
    IF &TEMP = F THEN GOTO A5
      ELSE DO
      WRITE ***INVALID CODE ENTERED***
      GOTO A4
    END
A5: WRITE ENTER TYPE OF INSTRUMENT, SINGLE OR MULTIPLE
    READ &TYPE
```

PROMPT PROGRAM CONTROL STATEMENTS

LINE STATEMENT

```
     IF &TYPE = SINGLE THEN GOTO OK
     IF &TYPE = MULTIPLE THEN GOTO OK
       ELSE DO
       WRITE ***INVALID ENTRY***
       GOTO A5
     END
 OK: IF &LIST = THEN GOTO ED
   ELSE SET &DSP = DELETE
 ED: EDIT 'SYS1,CLIST(DUMMY)' CNTL
  10 //ARS1AMRL JOB (ACCOUNTING AND JOB CARD INFORMATION),
  20 //   TIME=2,CLASS=D
  25 /&R.OUTPUT  AMRL  FORMS=1431,DEST=RMT27,COPIES=&COPIES,
  30 /&R.ROUTE  PRINT RMT27
  40 //STEP1 EXEC PGM=&TYPE.,PARM='&TEMP.,&DATANAME.'
  50 //STEPLIB DD DSN=AMRL01.PGMLIB,DISP=SHR
  55 //FT05F001 DD *
  56 &TEMP.&DATANAME
  60 //INPT DD DISP=OLD,
  70 //   DSN=AMRL01.&DATANAME..DATA
  80 //OUTT DD DISP=(,PASS,DELETE),
  90 //  DSN=AMRL01.&DATANAME..SASIN,UNIT=SYSDA,
  100 //  SPACE=(TRK,(15,10),RLSE),DCB=(RECFM=FB,LRECL=124,BLKSIZE=2480)
  120 //OTPT DD UNIT=SYSDA,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3059),
  130 //  DISP=(,PASS,DELETE),SPACE=(TRK,(15,10),RLSE),
  140 //  DSN=AMRL01.&DATANAME..&TEMP.L
  150 //STEP2  EXEC  PGM=IEBGENER
  160 //SYSPRINT DD SYSOUT=A
  163 //SYSIN DD DUMMY
  164 //SYSUT1 DD DSN=AMRL01.&DATANAME..&TEMP.L,DISP=(OLD,&DSP.)
  165 //SYSUT2 DD SYSOUT=(A,,AMRL),DCB=*.SYSUT1
  170 //STEP3  EXEC  SAS,PREFIX=SYS1
  180 //FT12F001 DD UNIT=SYSDA,DISP=(MOD,PASS,DELETE),
  190 //  DSN=AMRL01.&DATANAME..PL,
  200 //  SPACE=(TRK,(50,25),RLSE),DCB=(RECFM=VBA,LRECL=137,BLKSIZE=141)
  210 //SAVED DD UNIT=SYSDA,DISP=(OLD,&DSP.),
  220 //  DSN=AMRL01.&DATANAME..SASIN
  230 //SYSIN DD DSN=AMRL01.&SASPGM..DATA,DISP=SHR
  240 //      DD *
  250 TITLE2 &DATANAME.;
  260 //STEP4  EXEC PGM=IEBGENER
  265 //SYSIN DD DUMMY
  266 //SYSPRINT DD SYSOUT=A
  270 //SYSUT1 DD DSN=AMRL01.&DATANAME..PL,DISP=(OLD,&DSP.)
  280 //SYSUT2 DD SYSOUT=(A,,AMRL),DCB=(RECFM=VBA,LRECL=137,BLKSIZE=141)
      IF &TYPE = MULTIPLE THEN DO
       C 40 /,/ /
       60 //FT05F002 DD DISP=OLD,
```

PROMPT PROGRAM CONTROL STATEMENTS

LINE STATEMENT

```
      80 //FT01F001 DD DISP=(,PASS,DELETE),
      120 //FT06F001 DD UNIT=SYSDA,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3059),
     END
 290 //
SUBMIT
END
IF &LIST = THEN DO
  WRITE **THE FOLLOWING FILES WILL BE CREATED FROM THIS RUN:
  WRITE       'AMRL01.&DATANAME..SASIN'
  WRITE       'AMRL01.&DATANAME..&TEMP.L'
  WRITE       'AMRL01.&DATANAME..PL'
END
ELSE DO
  WRITE **OUTPUT WILL BE PRINTED AT DSAD
END
```

109 RECORDS PRINTED

Example 3

COMPUTER PROGRAM TO PLOT TEST DATA IN EXAMPLES 5 AND 6

```
DATA TEST;
OPTIONS PROCEDURE;
INFILE SAVED;
INPUT HOURS 1-4 (XI-X20) (20*RB4.);
MACRO AA / UMIN=35 UMAX=90 UINC=5 %
PROCEDURE SCATTER;
PLOT HOURS*X20 = '*' AA;
PLOT HOURS*AVERAGE = '*' HOURS*X1 = '-' HOURS*X2 = '.' AA OVERLAY;
TITLE 1 HOURS VERSUS TEMPERATURE DEGREES F;
```

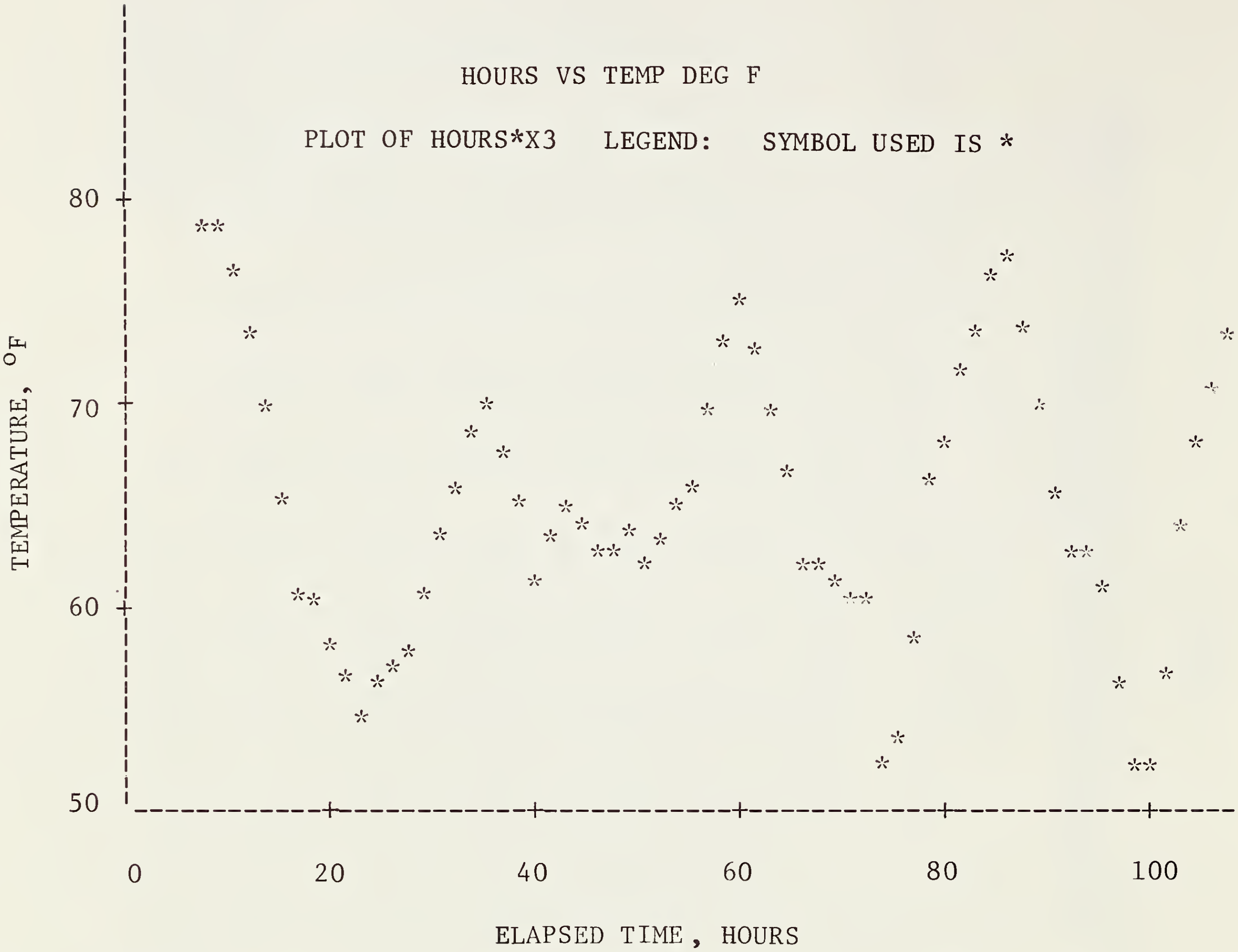
Example 4

REPRESENTATIVE SAMPLE OF COMPUTER OUTPUT LISTING TEMPERATURE RECORDED ON CASSETTE TAPE DURING TRANSIT TESTS

	Channel number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Hour	Temperature readings ^{o}F																			
0001	69	67	66	70	71	64	68	67	68	69	84	77	86	86	88	70	71	70	69	65
0002	69	67	66	70	71	64	68	67	68	69	84	78	86	86	88	70	71	70	69	65
0003	69	67	66	70	71	64	68	67	68	69	84	78	86	86	88	70	71	70	69	65
0004	70	68	68	70	71	65	69	67	68	69	86	78	89	89	90	70	71	69	70	67
0005	71	68	69	70	72	68	71	68	68	69	87	77	89	88	90	70	72	70	70	70
0006	72	68	71	70	73	69	72	68	68	69	84	74	86	84	86	70	73	72	71	71
0007	73	69	71	71	73	69	73	68	68	69	78	71	80	78	79	70	73	72	71	72
0008	73	69	71	71	73	70	73	68	68	70	74	68	75	73	75	70	73	72	71	72
0009	73	69	71	71	73	70	73	69	68	70	71	66	72	71	72	70	73	72	71	73
0010	73	70	71	71	73	70	73	69	68	70	70	65	70	70	70	70	73	73	71	73

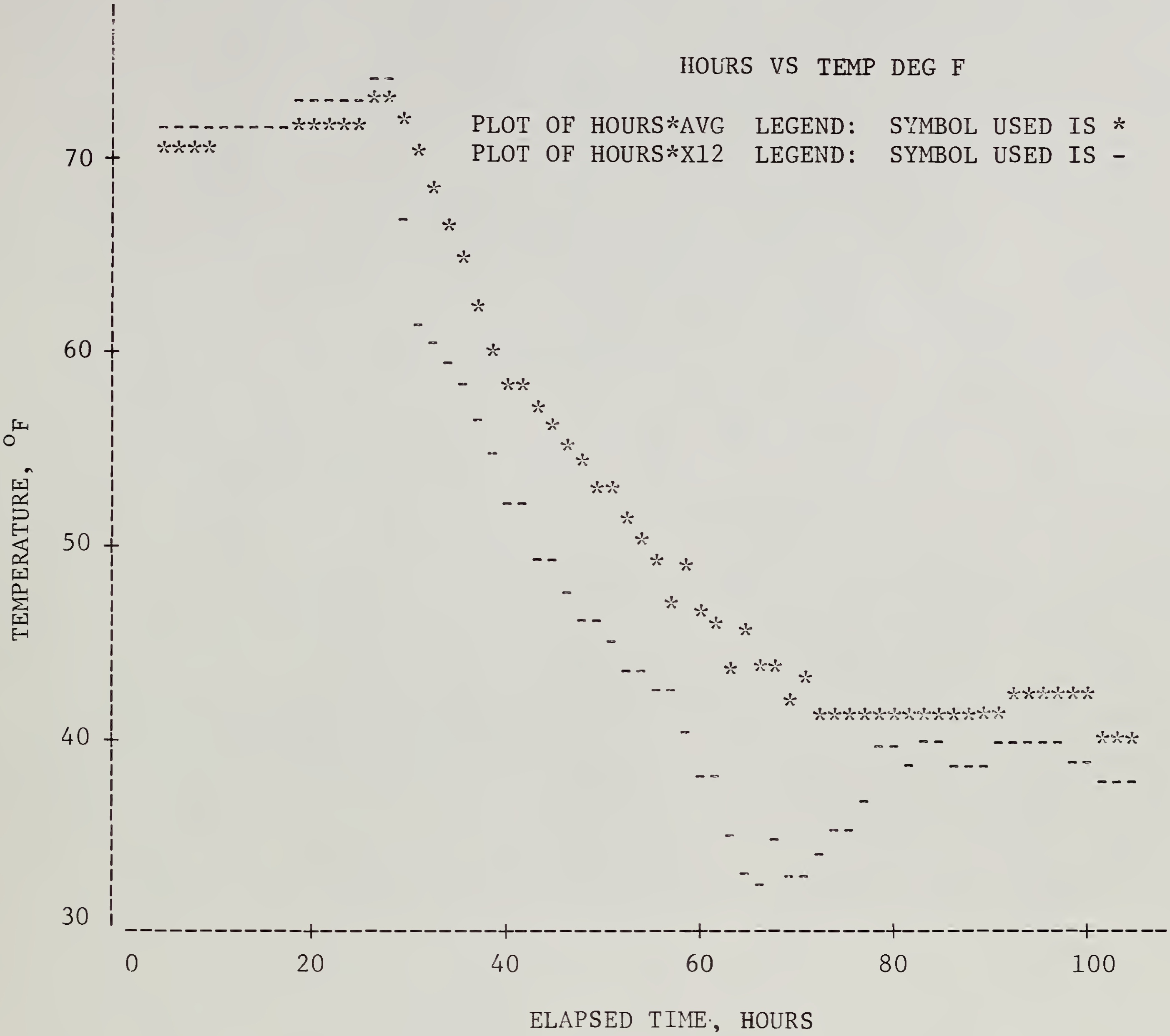
Example 5

COMPUTER-GENERATED GRAPH OF SINGLE SENSOR RECORDING OUTSIDE AIR TEMPERATURE (X3) DURING TEST



Example 6

COMPUTER-GENERATED GRAPH OF AVERAGE PRODUCE-PULP TEMPERATURE (AVG) AND DISCHARGE AIR TEMPERATURE (X12) IN REFRIGERATED VAN CONTAINER



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